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PROTECTION FROM INSECT AND VERTEBRATE PESTS IN RELATION TO CROP PRODUCTION

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PROTECTION FROM INSECT AND VERTEBRATE PESTS IN RELATION TO CROP PRODUCTION

by

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1. Insects and their allies, the ticks and mites, constitute a continuing threat to agricultural production. They are man's chief competitor for food and fiber. Every crop plant is subject to attack by a variety of insect pests. Damage may begin when the crop is planted, continue throughout its growing period, and persist even after harvest when products are placed in storage. In addition to such direct damage, insects are responsible for the spread of some of the most serious diseases affecting plants. Although arthropods take a heavy toll of agricultural production, many of these small creatures are beneficial to agriculture. Insect parasites and predators help to reduce the abundance of destructive insects, and the honey bees and other insects are essential for the pollination of many plants. In addition to the invertebrates, the vertebrate pests, including rodents and birds, compete with man for available food supplies and may also serve as reservoirs for important diseases. Thus, pest control for the welfare of man represents a major problem throughout the world.

Regulatory Programs Relating to Insect Control

2. The first line of defense in insect control involves quarantine activities. Most of the major crop pests in the United States have been accidentally introduced. Due to the increase in international travel and the high speed of modern transportation, adequate quarantines to detect and prevent the introduction of plant and animal pests are difficult to establish and maintain. However, this quarantine activity is regarded as one of the most essential and fruitful of the various insect-control efforts.

3. The United States maintains an insect-survey program designed to detect new introduced pests as quickly as possible and to obtain information on the seasonal abundance of established insects. Programs are maintained to prevent the spread of foreign pests and to deal with outbreaks of certain native pests.

4. Although public agencies contribute materially to the solution of insect problems by instituting various quarantine and control activities, most insect problems are met by the growers themselves, who follow the control procedures developed through research by public and industrial organizations.

Research and Progress on Various Methods of Insect Control

5. Many procedures for the control of the more important insect pests of crops and livestock have been investigated in the United States during the past 100 years that such research has been actively supported by Federal and State agencies. Major attention has been centered on the following procedures: Cultural and sanitary

measures; importation of parasites and predators of destructive insects as well as importation of insects for control of certain noxious weeds; development and use of insect pathogens; development of crop varieties that resist insect attack; use of attractants, including chemical or food baits, and light traps; and investigation of insecticides and other chemicals for the destruction of insects. In addition to the insect-control procedures mentioned, a new approach to insect control, involving the use of insects for their own destruction by releasing sexually sterile males, has during recent years received considerable attention in research.

Cultural Measures

6. Proper sanitary, cultural, or management practices are basic requirements in meeting some of the insect problems. However, the degree of control that can be achieved by such practices is often inadequate to meet the high standards of efficiency desired. Nevertheless, the level of insect populations can often be greatly reduced by following good cultural, management, or sanitary practices.

7. For example, the pink bollworm--a major threat to cotton production in the United States and one of the most destructive pests in a number of cotton-growing areas in the world--is relegated to the role of a minor pest of cotton in the United States because of the adoption of certain cultural measures (U.S.D.A. 1953). In south Texas, where the insect is most prevalent, regulations in force for a number of years establish each year the last date on which cotton may be planted and also a date before which all cotton must be harvested and the cotton stalks destroyed so as to prevent late season pink bollworm development and high overwintering populations. Thus, cultural measures, plus some control resulting from the use of insecticides for other cotton insects, generally prevent high losses due to the pink bollworm. The cultural measures prescribed for the pink bollworm also contribute materially to the control of the boll weevil in the pink bollworm areas. The application of such control measures requires knowledge of the life history and habits of the pest involved and, almost always, a community-wide cooperation by growers. Cultural measures alone, however, are often inadequate to solve the problem completely and supplementary measures should be developed in the event they are required.

Use of Parasites and Predators

8. The value of natural control factors, particularly parasites, predators, and insect pathogens, for regulating destructive insect populations is generally recognized. Experience in the United States indicates that for native insect pests the total influence of natural enemies is sometimes great enough to keep many of these pests under reasonable control. However, local or regional outbreaks of such native pests may occur from time to time; thus, to prevent excessive crop losses, control measures must be developed and applied when needed. Insects that have been accidentally introduced into the United States do not harm the usual number of natural enemies. In spite of efforts to introduce such enemies from the native home of the pest, natural control factors are generally less effective for these insects than for native pests.

9. Considerable attention is being given to the integration of chemicals and biological control. This technique involves the selection of suitable insecticides and dosage rates and the timing of applications so that minimum damage to the parasite and predator complex will occur. Several workers have demonstrated the value of limiting the use of insecticides as a supplement to natural control forces.

10. Excellent results have been obtained with introduced parasites and predators for controlling several destructive pests. These include the cottony-cushion scale (Icerya purchasi (Maskell)), Comstock mealy-bug (Pseudococcus comstocki (Kuwana)), and Japanese beetle (Popillia japonica(Newman)) in the U. S. and the citrus blackfly (Aleurocanthus woglumi (Ashby)), in the West Indies and Mexico. In many other

instances the introduction of parasites and predators has shown no significant control of the host insects. Although complete success is not often achieved, the investment in funds allocated to the search for and introduction of natural enemies is regarded as one of the most worthwhile that can be made to help meet insect problems.

11. The investigation of natural enemies of insect pests in various countries and the exchange of such insects represent ways in which countries can cooperate effectively in overall efforts to help meet insect problems. The U. S. Department of Agriculture has provided parasites or predators for many nations for release and possible establishment to help control destructive species, and it is prepared to lend any possible assistance to the development of mutual exchange of beneficial insects. A program of growing significance, which offers excellent opportunities for mutual cooperation in research, is maintained through the use of funds provided under the Agricultural Trade Development and Assistance Act of 1954, more commonly known as Public Law 480. In countries where such funds are available, it is thus possible to obtain support for research on biological agents that may be of mutual interest to agriculture in the United States and the cooperating country.

Insect Pathogens

12. Research on the use of insect pathogens to control destructive insects is gaining more and more interest and support. Insects are subject to attack by a wide variety of pathogenic organisms, including viruses, bacteria, protozoa, fungi, and mematodes. Under natural conditions they help regulate insect populations, as do parasites and predators. Like the parasites and predators, however, they generally do not provide sufficient control. Epidemics of pathogenic organisms among destructive insects are often delayed until the host has virtually destroyed the crop. However, application of mass-cultured pathogenic organisms offers the same opportunities for controlling destructive insects as those presented by insecticides. The potential advantage of disease organisms over insecticides is that insect pathogens are nearly always highly specific in their action against insects and thus are less likely than most insecticides to be hazardous to vertebrates. Examples of successful use of insect pathogens include a bacillus (B. popilliae Dutky) isolated from the Japanese beetle, a cytoplasmic virus on the pine processionary moth (Thaumetopoca pityocampa) and a polyhedral virus and Bacillus thuringiensis var. thuringiensis on the alfalfa caterpillar (Colias eurethema Boisduval). B. thuringiensis var thuringiensis has been registered for use in the United States and is recommended for controlling a variety of insects affecting crops.

13. The exchange of information and cultures of insect pathogens as an aid in the development of promising insect disease organisms for controlling destructive insects represents another way that mutual benefits can be obtained through cooperation among different countries.

The Development of Crop Varieties Resistant to Insect Attack

14. In the United States entomologists and plant breeders have considerable research underway to develop crop varieties that resist insect attack. This desirable approach to insect control has, however, received far too little attention. Research on specific insects attacking certain grain and forage crops in the United States has met with substantial success. The control of the Hessian fly (Phytophaga destructor (Say)), on wheat is one of the most outstanding examples of this success. Other examples are varieties of alfalfa that are highly resistant to the spotted alfalfa aphid (Therioaphis maculata (Burton)), sweet corn varieties that are resistant to attack by the corn earworm (Heliothis zea (Boddie)), field corn varieties that are resistent to attack by the European corn borer (Ostrinia nubilalis (Hubner)), and sugarcane varieties that resist attack by the sugarcane borer (Diatraca saccharalis (F.)).

15. One of the chief disadvantages of the varietal-resistance approach to insect control is the long period of research and development usually necessary to find insect-resistant germ plasm in a crop and to incorporate this character into suitable varieties adapted to different regions or countries. However, once the resistance character has been incorporated, no additional cost for protecting the crop is necessary and no side effects to other organisms will result. From a long-range and world-wide viewpoint, this approach to insect control needs to be given appropriate attention. Research in this area also lends itself to effective mutual cooperation between countries. Insect-resistant germ plasm can be exchanged and used in breeding-improvement programs.

Use of Insecticides

16. The extensive use of insecticides is a major factor in the high degree of productivity of crops in the United States. As shown in Table 1, a wide variety of insecticides is available for controlling the many kinds of insects affecting agricultural crops.

17. Insecticides are necessary for a highly efficient agricultural economy, but their extensive use has led to several potential-hazard problems that are being investigated intensively by industrially and publicly supported institutions in efforts to resolve them. Many of the insecticides are of special value in protecting crops and livestock from insect attack because of their persistant residual action. However, this feature which is desirable from the standpoint of insect control, intensifies the problem of avoiding excessive residues on crops grown for human consumption. The problem is further complicated by the possible occurrence on animal feeds of insecticide residues, which may in turn be stored in meat and milk when the feed is consumed by livestock. The Federal Government and the different States have enacted laws and regulations that establish tolerances for pesticide residues in raw agricultural commodities. The U.S. Department of Agriculture and comparable state agencies are responsible for enforcing such laws and regulations. Insecticides, to be marketed, must have been shown to meet certain standards of efficiency and safety before they can be registered and sold. Increased attention is also being devoted in research by Industry and public institutions to the development of kinds of insecticides that do not leave residues in raw agricultural commodities.

18. Another problem that is of concern is the adverse effects of insecticides on beneficial insects, particularly parasites and predators. The adverse effects on the honey bee and other pollinating insects of certain insecticides are of concern to bee keepers and farmers who depend on honey bees for the pollination of crops. Conservationists are apprehensive about the immediate and long-range effects of pesticides on fish and wildlife. Many instances of loss of wildlife in localized areas due to insecticides are experienced each year. However, there is no indication that the overall abundance of fish and game has been reduced. Wildlife biologists and entomologists are developing closer cooperation in their research in efforts to develop insecticides and ways of using them to minimize such hazards.

19. The problem of insects becoming resistant to insecticides is also a matter of increasing concern. Basic investigations are underway by a number of State and Federal research institutions to help resolve this problem. Thus far it has been possible to develop satisfactory substitute insecticides for the insects that have become resistant to different insecticides.

Other Methods of Insect Control

20. In addition to the more conventional ways of meeting insect problems, new approaches to insect control that may be of great significance in the future are under investigation. The discovery of materials that are highly attrative to males

of certain tropical fruit flies represents an important advance in the detection and control of these insects of major importance as pests of fruits and vegetables in many parts of the world. Lures have been useful in trapping the oriental fruit fly (Dacus dorsalis Hendal), the Mediterranean fruit fly (Ceratitis capitata (Wiedemann)) and the melon fly (D. cucurbitae Coquillet). The use of protein hydrolysate bait-sprays for the Mediterranean and other fruit flies also represents a major advance in control of fruit flies.

21. Another major advance in the insect-attractant field has been the identification of the chemical structure and synthesis of the male sex attractant present in the virgin female of the gypsy moth (Porthetria dispar (Linn)). Similar research on the insect and on biochemical aspects of sex attractants would seem to offer most promising fields of investigation.

22. The development of the sterile-male concept of insect control has been applied successfully for the eradication of the screw-worm (Cochliomyia hominivorax (Coquerel)), a major livestock pest, from the southeastern United States. The method involves the production and release of a large number of sterile insects. Research is underway to explore this approach for the control of tropical fruit fly species, the pink bollworm, the boll weevil, codling moth (Carpocapsa pomonella (L.)) and the tobacco hornworm (Protoparce sexta (Johannson). Two methods of producing sterility are under investigation--(1) by exposure to gamma radiation and (2) by exposure to chemicals.

23. Application of the chemosterilant method induces sterility in insects with less adverse effects on the vigor and competition in males than use of gamma radiation. The sterility principle promises a new approach which should apply to vertebrate as well as invertebrate pests. However, much research is needed on the autocidal approach to the control of invertebrate or vertebrate pests, whether it involves producing and releasing sterile organisms or inducing sterility in the natural population. The utilization of strong male sex lures and other attractants in insects and the application of chemicals that produce sterility now being developed offer two systems that, when combined, have the potential of producing maximum results in regulating insect populations.

Vertebrate-Pest Problems

24. In the control of vertebrate pests the target species often plays a dual role, being a destructive pest under some situations, but, under others, of value to human existence. In some parts of the world most of the birds and many species of mammals and fresh-water fish are protected and their populations maintained at the highest possible level, largely for the aesthetic and recreational values their presence offers. Although their contribution to the food supply may be appreciable, this benefit is not critical in providing an adequate diet for the people of these areas. On the other hand, in far larger areas of the globe, a handful of sparrows, a rodent from the field, or a carp from the irrigation canal will at times provide the only meat available to supplement a basic vegetable diet. Local populations of vertebrates that in one area can be sacrificed to protect some more valuable resource, such as rabbits in Australia, deer in New Zealand, ground squirrels and blackbirds by the millions in the United States, in another area must be repelled or taken in such a manner as to leave them suitable for consumption by humans or domestic animals. Even the lowly meadow mouse (Microtus), during years of abundance, has been laboriously captured and converted into animal feeds and soil fertilizers.

25. Presently known pesticides allow a versatility of materials for rodent control. It is possible to prepare highly attractive food baits or to effect control with a carrier no more critical than water. Some of these rodent poisons are both primary and secondary hazards to beneficial wildlife associated with rodents and the utility and safety of these poisons depends on their application by responsible well-trained

operators. Other rodenticides do not present a secondary hazard, and a few, when properly formulated, are quite specific for a narrow range of vertebrate species. Several of the toxicants provide a quick knockdown, but with others the onset of symptoms is delayed, a feature which confers a higher degree of control than would be possible when the death of one individual warns other members of a feeding group. When outbreaks of human disease make necessary the quick suppression of the rodent-vector, several of these rodenticides can be adapted for use as baits distributed by aircraft or mechanized ground equipment. Chemical rodenticides are known that are effective when applied as liquid sprays to field habitats, or even buildings. However, in either of the techniques that call for the toxicant to be blanketed over the habitat, complete freedom from adverse effects on associated beneficial species is not yet possible. Other rodenticides are effective as powders dusted into burrows or animal trails, or as pastes and foams smeared where they will be picked up on the feet and fur of the passing rodents. The effectiveness of most of these rodenticides is dependent on subsequent grooming by the animal and resulting oral ingestion, but several can cause death by being directly absorbed through intact skin. The phytotoxicities of most of the vertebrate pesticides are known so that is is possible to effectively protect seed from mammal and bird attack without adversely affecting germination or subsequent growth of the seedling. In fact, some new candidate rodenticides can be translocated from soil placement into the growing plant, thus creating a living toxic bait. Finally there are rodenticides that are effective as gases for the fumigation of burrows, stored food products, and buildings.

26. An important aspect of some vertebrate-control programs is the ability to control the ectoparasite at the same time. It has been shown that the incidence of disease in a plague area temporarily increases following control of rodents, since the disease vectors (fleas, lice) are literally forced to transfer to humans and domestic animals for a blood meal. Where it is possible to use gases such as cyanide, methyl bromide, or chloropicrin for the fumigation of rodent burrows, store food products, and infested buildings, control of ectoparasites is accomplished easily enough. When fumigation with gases cannot be employed, use of a chlorinated hydrocarbon insecticide as a tracking powder in connection with feeding stations, stocked with food that contains a slow-acting rodenticide, results in the rodent transferring the insecticide on its fur to its nest site before death. A promising solution, and the subject of much current research, is the use of slow-acting systemic rodenticides that eliminate the ectoparasites by circulation in the blood of the host prior to its death. Certain organic phosphates and carbamates appear useful in this regard.

27. The remoteness of an area, the economic status of its peoples, and the availability of technical instruction and assistance dictate that the widest possible approach be taken in the solution of vertebrate-pest problems. New methods for the control of vertebrates arise from many diverse programs in the United States. The dynamic synthesis programs of the agricultural chemical and drug industries provide experimental basic material at a rate that taxes facilities for biological evaluation. It has been estimated that approximately 2,000 new chemicals and drugs which are of "probable utility" can be made available each year for evaluation and development as vertebrate pesticides.

28. In research on entirely new compounds, emphasis is in the direction of the following: (1) More specific compounds, that is, materials that will eliminate a given vertebrate species with little or no adverse effect on associated beneficial life; (2) repellents for protecting agricultural crops, forest reproduction, and range browse plants against browsing by rabbits, porcupines, deer, and even domestic livestock; (3) certain chemicals particularly those that can be translocated into living seeds and plants to render them temporarily unpalatable during transplanting and initial establishment of the plant on the site; (4) chemosterilants having an effective period of 1 year for long-range control of mammalian predators and certain bird pests; and (5) anaesthetizing and stupefying compounds that can be used with baits to take vertebrates alive for further utilization or selection.

29. In addition to the many well-known rodenticides and vertebrate-control chemicals, a library of new candidate materials is growing rapidly. Seldom does the chemical per se have all the attributes of an effective pesticide. For example, a toxicant may prove to be ideal for a given purpose, with the exception that vertebrates will not voluntarily consume baits containing it. Rather exciting new formulation techniques now permit the masking of the taste, or effect the delay of the onset of warning symptoms by (1) microencapsulation, and (2) formation of inclusion compounds, "clathrates." Even some degree of safety can be built into the formulation by such devices as (1) the inclusion of emetics that have little or no effect on the rodent to be controlled but act quickly on children, domestic pets, and livestock that accidentally ingest the baits; or (2) the off-coloring of poisoned grains used in rodent control to deter birds from feeding thereon.

30. Many improvements in standard products have been made. For example, synergists have been found that permit effective use of rotenone in the control of trash fish at half the former amount needed per-acre foot of water. A new companion product to be incorporated with anticoagulant rodenticides promises to materially improve the control of house mice (Mus musculus). In another such product a change in solvent was found to increase the toxicity of the active ingredient many fold.

31. Mechanical means of vertebrate control are far from being outmoded in modern practice. The responses of birds to light of different colors and intensity, to amplified sound, to recorded distress calls, and to radar and associated electromagnetic fields are receiving intensive study.

32. Recently, tractor-drawn, hydraulic-controlled equipment for constructing subsurface tunnels or runways, called a "burrow builder," has been perfected for metering and placing poisoned baits in underground runways that intersect natural subsurface workings of the destructive pocket gopher (Geomyidae). Two goals are achieved: Control operations are more rapidly accomplished, and the placement of the poison bait avoids any hazard for domestic livestock and beneficial wildlife.

33. The trap, historically one of the first of man's tools in his competition with other vertebrates, continues to serve him, being found in every conceivable size and type, with a choice as to whether the animal is to be taken alive or dead, singly or in groups. A trap may be as simple as a fine-mist net stretched across the flight path of birds; a light-to-carry, easy-to-set loop snare, to replace the burdensome steel trap for taking bear (Euarctos); or at the other extreme, a collapsible, barn-sized trap equipped with flood lights to attract birds by the thousands when flushed from their roosts at night.

34. The problems of pest control as they relate to food production and public health merit international effort and cooperation. The United States is willing to share its knowledge in the technology of management of pest populations together with new information as it evolves from an extensive research and development program.

Table I

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Major types of insects involved in crop production in the United States and some of the more commonly used insecticides employed for their control

Crop Pests	Insecticides Employed	Remarks
Cotton insects	DDT, toxaphene, dieldrin, endrin, BHC, calcium arsenate, Guthion, methyl parathion, malathion, Aramite, demeton, carbophenothion, sulfur, Sevin	
Vegatable insects	DDT, malathion, methoxychlor, toxaphene, rotenone, pyrethrum, Sevin, parathion, demeton, naled, Phosdrin, Guthion, endosulfan, diazinon	Careful attention to dosage, formulation, and timing of treatments in relation to harvest must be observed in order to aviod residues or to meet tolerances
Corn, rice, sorghum, and small grain insects	DDT, toxaphene, methoxychlor, dieldrin, endrin, Sevin, parathion, diazinon, naled, malathion, Phosdrin	Same as above
Fruit insects	DDT, methoxychlor, lead arsenate, rotenone, Sevin, malathion, parathion, Guthion, diazinon, EPN, demeton, endosulfan, Aramite, ethion, carbophenothion, Tedion, Kelthane, ovex	Same as above
Legume and grass insects	DDT, methoxychlor, dieldrin, aldrin, heptachlor, lindane, toxaphene, parathion, demeton, malathion, Phosdrin, naled, diazinon, Sevin	Same as above
Sugarcane and Sugar beets	parathion, demeton, Dylox, naled, phorate, DDT, carbophenothion, endrin, ryania	Residue problem may be critical if beet tops are used as animal feeds
Tobacco insects	TDE, endrin, Guthion, endosulfan, parathion	Bacillus thuringiensis, var. thuringiensis, an insect pathogen is used for tobacco hornworm and bud worm control
Soil insects	Aldrin, dieldrin, heptachlor, chlordane, DDT, diazinon	

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